Proceedings of the Ninth International Conference on Urban Pests
Matthew P. Davies, Carolin Pfeiffer, and William H Robinson (editors) 2017
Printed by Pureprint Group, Crowson House, Uckfield, East Sussex TN22 1PH UK

EVALUATION OF MOSQUITO BARRIER APPLICATIONS USING LAMBDA-CYHALOTHRIN AND PYRIPROXYFEN IN THE UNITED STATES

NICOLA T. GALLAGHER, ELRAY ROPER, CHRIS T. KEEFER, MARK COFFELT, AND CLAY W. SCHERER
Syngenta Crop Protection, LLC.

Abstract *Aedes albopictus* is an invasive mosquito in the United States and also a competent vector for many viruses. As an aggressive human biter, this mosquitoes is often the primary pest species eliciting complaints from the public in areas where they occur. This mosquito will readily utilize artificial containers for breeding and thus has adapted well to suburban and urban habitats. Barrier treatments for suppression of anthropophagic mosquitoes in the spatial scale of a typical suburban backyard show promise to provide meaningful reduction of nuisance mosquitoes. In this paper, we report the results of both a laboratory and field trial evaluating the performance and residual toxicity of Demand® CS insecticide (lambda-cyhalothrin) and Archer® insect growth regulator (pyriproxyfen) when barrier treatments are created by targeting treatments with mist blowers to low-lying foliage.

Key words *Aedes*, management, insect growth regulator, lambda-cyhalothrin, pyriproxyfen, foliage**.**

INTRODUCTION

Aedes albopictus is the most invasive vector mosquito in the world (Bonizzoni et al. 2013) and a competent vector for many viruses (Benedict et al., 2007). As an aggressive human biter, this mosquito is often the primary pest species eliciting complaints from the public in areas where it occurs (Farajollahi, 2009). Because it readily utilizes artificial containers for breeding, it has adapted well to suburban and urban habitats (Barker et al. 2004). Residual pesticides applied to mosquito resting sites in vegetation have been shown to reduce pest mosquito populations (Trout et al., 2007; Amoo et al., 2008; Doyle et al., 2009).

Syngenta and outside cooperator trials have evaluated the efficacy of Demand CS (lambda-cyhalothrin, Syngenta Crop Protection, Inc., Greensboro, NC) and Archer IGR (pyriproxyfen, Syngenta Crop Protection, Inc., Greensboro, NC) for the control of mosquitoes. The focus of such studies evaluated: 1) the residual toxicity under field conditions of lambda-cyhalothrin to *Ae. albopictus*, and 2) barrier pesticide applications in mosquito infested backyards using lambda-cyhalothrin, pyriproxyfen, and a combination of both products on *Ae. albopictus* populations.

MATERIALS AND METHODS

Residual Performance on Landscape Vegetation

Five plant species common to landscaped areas in southwestern Virginia were selected: *Miscanthus sinensis*, *Buxus* spp., *Rhododendron* X 'Chionoides', *Thuja occidentalis* and *Lonicera japonica*. Plants were evenly spaced in a 6.1 meter^2 plot and were exposed to natural environmental conditions. Treatments were 0.06% lambda-cyhalothrin, 0.03% lambda-cyhalothrin or water as a control. Treatments were

INTRODUCTION

Aedes albopictus is the most invasive vector mosquito in the world (Bonizzoni et al. 2013) and a competent vector for many viruses (Benedict et al., 2007). As an aggressive human biter, this mosquito is often the primary pest species eliciting complaints from the public in areas where it occurs (Farajollahi, 2009). Because it readily utilizes artificial containers for breeding, it has adapted well to suburban and urban habitats (Barker et al. 2004). Residual pesticides applied to mosquito resting sites in vegetation have been shown to reduce pest mosquito populations (Trout et al., 2007; Amoo et al., 2008; Doyle et al., 2009).

Syngenta and outside cooperator trials have evaluated the efficacy of Demand CS (lambda-cyhalothrin, Syngenta Crop Protection, Inc., Greensboro, NC) and Archer IGR (pyriproxyfen, Syngenta Crop Protection, Inc., Greensboro, NC) for the control of mosquitoes. The focus of such studies evaluated: 1) the residual toxicity under field conditions of lambda-cyhalothrin to *Ae. albopictus*, and 2) barrier pesticide applications in mosquito infested backyards using lambda-cyhalothrin, pyriproxyfen, and a combination of both products on *Ae. albopictus* populations.

MATERIALS AND METHODS

Residual Performance on Landscape Vegetation

Five plant species common to landscaped areas in southwestern Virginia were selected: *Miscanthus sinensis*, *Buxus* spp., *Rhododendron* X 'Chionoides', *Thuja occidentalis* and *Lonicera japonica*. Plants were evenly spaced in a 6.1 meter^2 plot and were exposed to natural environmental conditions. Treatments were 0.06% lambda-cyhalothrin, 0.03% lambda-cyhalothrin or water as a control. Treatments were applied using a Stihl sr200 mist blower just to the point of runoff, taking care to ensure that both the top and undersides of the leaves were treated. Leaves were sampled from the plants the day after spraying and at the same time each week thereafter for 8 weeks, omitting weeks 5 and 7, to conduct bioassays. A leaf was placed in each bioassay vial and 10 female mosquitoes (between 2-3 days of age) were added. Knockdown was evaluated after a 1-hour exposure, and mortality was evaluated at 24 hours. The effect of plant species on knockdown and mortality were analyzed using 1-way ANOVA followed by Tukey's HSD. T-tests were used to analyze the effect of concentration on total mean knockdown and total mean mortality. All statistical analyses were carried out using JMP Pro 11.0.0 (SAS, 2013) at a significance level of $\alpha = 0.05$.

Barrier Applications in a Residential Setting

In a residential setting in Lexington, KY, a randomized complete block design was used to compare lambda-cyhalothrin alone and lambda-cyhalothrin combined with pyriproxyfen as a tank mix. One suburban residence in each of five neighborhoods (the blocking factor) were randomly assigned one of the two treatments or a water-only control. Insecticides were applied at 0.06% lambda-cyhalothrin and 0.1% pyriproxyfen. Treatments were applied with a Stihl sr450 mist blower, directed to perimeter vegetation shorter than 2 meters. Mosquito populations were sampled using CO_2 traps, gravid traps, human landing rates, and ovitraps. Sampling was conducted weekly for 3 weeks pre-treatment and 8 weeks post-treatment when treatment effects had dissipated. Data were analyzed with Proc Mixed by ANOVA repeated measures and means were separated by Tukey's Least Square Means test (SAS Institute 2001).

RESULTS AND DISCUSSION

Residual Performance on Landscape Vegetation

The total mean knockdown of mosquitoes after a 1-hour exposure was significantly higher for the 0.06% lambda-cyhalothrin application rate than for the 0.03% lambda-cyhalothrin rate (76.3% vs. 43.3%) (t-test, $P<0.01$). Regardless of application rate, plant species did not have a significant effect on knockdown (Table 1).

Table 1. Mean percent knockdown (SE) of *Aedes albopictus* 1 h after exposure to leaves treated with different concentrations of lambda-cyhalothrin.

Plant	Concentration (%)	
	0.03	**0.06**
Miscanthus sinensis	49.5 (0.08)	90.0 (2.7)
Rhododendron X 'Chionoides'	45.7 (8.2)	83.8 (4.4)
Thuja occidentalis	40.4 (9.8)	69.0 (8.6)
Buxus spp.	44.8 (9.7)	69.0 (7.7)
Lonicera japonica	36.7 (8.4)	69.5 (8.9)
Mean	43.4 (0.04)	76.3 (0.03)

Mean percent mortality after a 24-hour exposure was affected by both application rate and plant species (Table 2). Mortality was higher for the 0.06% application rate than for the 0.03% rate (93.4% vs. 79.5%) (t-test, $P<0.01$). Mortality was highest on *M. sinensis*, *Rhododendron*, and *T. occidentalis* and lowest on *L. japonica* regardless of application rate (Table 2).

Table 2. Mean percent mortality (SE) of *Aedes albopictus* after 24-hour exposure to leaves treated with different concentrations of lambda-cyhalothrin.

Plant	Concentration (%)	
	0.03	**0.06**
Miscanthus sinensis	94.3 (1.8) a	99.5 (0.5) a
Rhododendron X 'Chionoides'	86.7 (3.5) a,b	95.2 (2.3) a,b
Thuja occidentalis	84.8 (3.4) a,b	94.8 (1.8) a,b
Buxus spp.	72.9 (5.4) b,c	92.9 (2.9) a,b
Lonicera japonica	59.0 (9.0) c	84.8 (5.6) b
Mean	**79.5 (0.03)**	**93.4 (0.01)**

Means within each column followed by the same letter are not significantly different. Tukeys HSD test ($P > 0.05$).

Table 3. Total mosquitoes captured by treatment throughout the entire season post-treatment (7/8/2014 – 9/10/2014).

Post-Treatment Trap Totals	Treatment and Concentration (%)		
	lambda-cyhalothrin (0.06)	lambda-cyhalothrin (0.06) and pyriproxyfen (0.1)	Water
CO_2 Trap	102	68	763
Gravid Trap	133	96	489
Human Landing Rate	59	84	224
Ovitrap	89	35	1,788
NOTE: Both insecticide treatments significantly ($P < 0.05$) reduced mosquitoes relative to control, but there were no statistical differences between the two treatments except for ovitrap counts			

Barrier Applications in a Residential Setting

Both lambda-cyhalothrin and lambda-cyhalothrin combined with pyriproxyfen effectively reduced overall mosquito numbers during the 8 week post-treatment evaluation (Table 3). With respect to effect on individual species, *Aedes*/*Ochlerotatus* spp. were reduced the most and were effectively reduced by both treatments (Table 4). Except for the reduction in larvae collected from ovitraps ($P<0.05$), there were no significant differences between lambda-cyhalothrin and lambda-cyhalothrin combined with pyriproxyfen
(Table 3). However, there was a consistent pattern of lambda-cyhalothrin combined with pyriproxyfen producing a lower mosquito population than did lambda-cyhalothrin alone (Table 3).

Table 4. Percentage reduction of mosquito species relative to control throughout the entire season post-treatment (7/8/2014 – 9/10/2014).

Species	Treatment and Concentration (%)	
	lambda-cyhalothrin (0.06)	lambda-cyhalothrin (0.06) and pyriproxyfen (0.1)
Aedes albopictus	87	78
Culex pipiens	34	61
Aedes vexans	72	79
Anopheles spp.	16	44
NOTE: Both insecticide treatments significantly ($P < 0.05$) reduced mosquitoes relative to control, but there were no statistical differences between the two treatments		

CONCLUSIONS

In conclusion, these studies show that lambda-cyhalothrin is an effective insecticide for use as barrier sprays against nuisance mosquitoes such as *Ae. albopictus.* Plant species does not seem to have a major effect on efficacy, although care should be taken to ensure that the product is evenly applied to all surfaces of the leaves. Pyriproxyfen does not cause immediate mortality or impair adult activity (Kawada et al. 1993), but it is effective on immature mosquitoes at extraordinarily low concentrations (LC_{50} in *Ae*. *albopictus* 0.012 ppb and *Ae. aegypti* is 0.023 ppb) (Gaugler et al. 2012). Results from this trial are encouraging in that pyriproxyfen, when used in combination with lambda-cyhalothrin, may further reduce mosquito populations and be used as an effective component of barrier applications. *Ae*. *albopictus* control is challenging, but residual insecticide applications to vegetation can provide long lasting suppression against nuisance mosquitoes and can be incorporated as part of an integrated mosquito management program.

ACKNOWLEDGEMENTS

The authors acknowledge the following institutions for their assistance and work in the mosquito control research lab and field trials during 2014-2015: Department of Entomology, Virginia Polytechnic Institute and State University and Department of Entomology, The University of Kentucky.

REFERENCES CITED

Amoo, A., R.-D. Xue, W. Qualls, B. Quinn, and U. Bernier. 2008. Residual efficacy of field-applied permethrin, d-phenothrin, and resmethrin on plant foliage against adult mosquitoes. J Am Mosq Control Assoc 24: 543-549.

Barker, C.M., C.C. Brewster and S.L. Paulson. 2004. Spatiotemporal oviposition and habitat preferences of *Ochlerotatus triseriatus* and *Aedes albopictus* in an emerging focus of La Crosse virus. J Am Mosq Control Assoc. 19: 382-391.

Benedict, M. Q., R. S. Levine, W. A. Hawley, and L. P. Lounibos. 2007. Spread of the tiger: global risk of invasion by the mosquito *Aedes albopictus*. Vector-Borne and Zoonotic Diseases 7: 76-85.

Bonizzoni, M., G. Gasperi, X. Chen, and A. A. James. 2013. The invasive mosquito species *Aedes albopictus*: current knowledge and future perspectives. Trends Parasitol 29: 460- 468.

Doyle, M. A., D. L. Kline, S. A. Allan, and P. E. Kaufman. 2009. Efficacy of residual bifenthrin applied to landscape vegetation against *Aedes albopictus*. . J Am Mosq Control Assoc 25: 179-183.

Farajollahi, A., and M. P. Nelder. 2009. Changes in *Aedes albopictus* (Diptera: Culicidae) populations in New Jersey and implications for arbovirus transmission. J Med Entomol 46: 1220-1224.

Gaugler, R., D. Suman, and Y. Wang. 2012. An autodissemination station for the transfer of an insect growth regulator to mosquito oviposition sites. Med. Vet. Entomol. 26: 37-45.

Kawada, H., Y. Shono, T. Ito, and Y. Abe. 1993. Laboratory evaluation of insect growth regulators against several species of anopheline mosquitoes. Jap. J. Sanit. Zool. 44: 349- 349.

SAS (2013) JMP version 11.0.0. SAS Institute, Cary, NC.

Trout, R., G. Brown, M. Potter, and J. Hubbard. 2007. Efficacy of two pyrethroid insecticides applied as barrier treatments for managing mosquito (Diptera: Culicidae) populations in suburban residential properties. J Med Entomol 44: 470-477.